# INTEGRATION OF MECHANICAL IMPULSES OF THE HEART

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Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny Vol. 51,
No. 1, pp. 107-109, January, 1961
Original article submitted February 18, 1960

Present methods of ballistocardiography consist in obtaining oscillograms of the mechanical vibrations of the human body arising as a consequence of the external work of the heart. With each systolic beat of the heart, there is a complex of mechanical waves which is received from the human body by means of various pickup devices. Specialists studying ballistocardiograms distinguish three main types of curves obtained by means of various pickup devices – curves for shifts, rate, and acceleration.

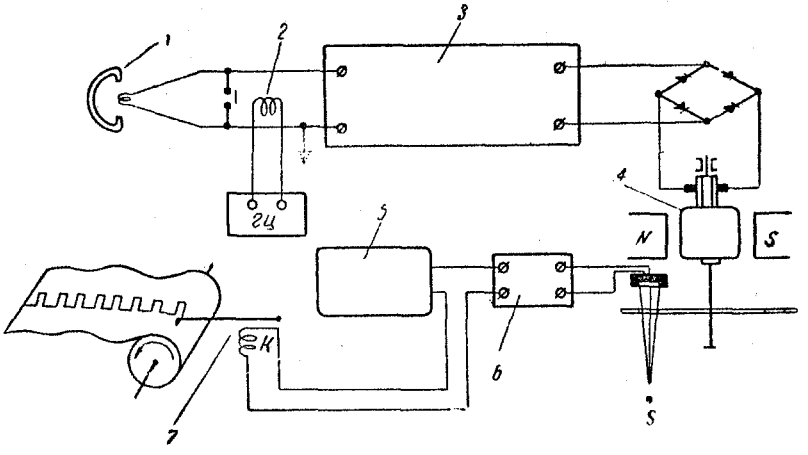


Figure 1. Diagram of a device for integrating the work of the heart: 1) magnetoelectric pickup; 2) polarized relay of the RP-7 type; 3) 4U12 amplifier; 4) ampere-hour meter; 5) SB-1M/100 type meter; 6) photocascade; 7) marker with kymograph.

The diversity of ballistocardiogram pictures in pathological conditions of the heart, as well as the absence of standard equipment, as yet make it impossible to compare the results of different investigations. In connection with the difficulties of evaluating ballistocardiograms, we decided to employ the integration method, which we developed for measuring the biological currents of the brain and muscles, and for measuring the mechanical impulses of the heart.

The mechanical impulses of the heart received by the pickup device and converted to an electrical value are intensified by means of an electronic amplifier, are rectified, and are conducted to a volt-hour (or ampere-hour) meter.

The Results of Measurements of the Work of the Heart Before and After Physical Stress

| Family name of subject | Ballistic impulses of the heart recorded by the integrator and expressed in conditional units | | Reactive difference, $R = P_2 - P_1$ |
|---|---|---|---|
| | without stress for 3 min, $P_1$ | after stress for 3 min, $P_2$ | |
| B-rova | 36 | 87 | 51 |
| Z-kova | 42 | 71 | 29 |
| Z-bova | 45 | 65 | 20 |

This equipment is capable of automatically computing the work of the heart for any given interval of time. The meter readings expressed in numerical units are proportional to the areas included under the ballistocardiogram curve taken during the same period of time. The proposed method does not permit the differentiation of the form factor of the curve; nevertheless, this is a simple method of quantitative measurement. The meter readings are conditional units which are connected by a certain coefficient of proportionality with the forces acting on the pickup device.

Such a meter can measure the work of the heart over a period of several tens of minutes. During prolonged measurement with the aid of the integrator, average values of the mechanical impulses conducted from the pickup device are determined quite accurately; occasional deviations from these values are eliminated due to averaging carried out over a long period of time. In a particular case, the meter reading for five minutes will be proportional to the sum of the areas under the ballistocardiogram curve, the extent of which is 12 m.

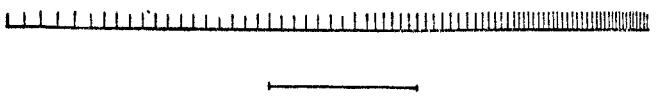

Fig. 2. Kymogram (time scale – 1 min) showing the distribution in time of the work of the heart following physical stress (20 deep-knee bends with arms thrown forward in 20 sec).

We used a magnetoelectric pickup in which the coil of wire oscillated in the field of a stationary magnet. This pickup device, proposed by R. M. Baevskii, is a small table measuring 300 × 100 × 80 mm. Springy steel plates serve as its four supports. The pickup device is fastened to the cot in such a manner that its lower base is stationary. The feet of the subject to be observed (lower part of the shin) are placed in the upper yokes.

The electromotive forces developed by the pickup device are converted by a special amplifying mechanism. We used a 4U12 type amplifier for movie equipment. The remodeling of this device consisted in using an electromechanical vibrator with a frequency of 200 hertz at the point of entry, which closes the input of the amplifier (Fig. 1). A polarized relay of the RP-7 type was used as the vibrator, the coil of which was fed from a circuit which twice doubled the frequency of the alternating current of the city network. Thus, the amplifying device works on a carrier frequency of 200 hertz.

The output of the amplifier device after the transformer has a rectifying bridge consisting of four DGTs-23 type rectifier elements. The rectified electrical impulses enter the ampere-hour meter, which is a magnetoelectric motor, the number of rotations of which is a function of current and time. In our equipment, we used a meter made by Hartman and Brown.* A disk with three rectangular-shaped openings is fastened on the axis of the meter. A photocell is situated on one side of the disk, while on the other side, a flashlight bulb enclosed in a tube. With each rotation of the disk, the photoelectric circuit produces three impulses which activate the SB-1M/100 type impulse meter, which is well known to biologists engaged in measuring the radiation of labeled atoms. An electromagnetic marker K is cut in after the impulse meter (see Fig. 1). The number of loops of winding of the marker is in keeping with the photoelectric circuit. By means of this device, markings are put on the kymograph tape.

Thus, by means of the SB-1M/100 meter, the equipment makes it possible to summarize the work of the heart for any given interval of time. In the table, data are given of measurements of various persons before and

*At the present time, the Leningrad factory LEMZ has begun to put out M-642 type meters, which are suitable for these circuits.

after physical stress (20 deep-knee bends with arms thrown forward in 20 sec) for equal intervals of time of 3 min each.

As is well known, when physical stress is removed, the heart quickly curtails its work. Inasmuch as the process of increasing or decreasing the work of the heart develops with time, we consider it rational to obtain characteristics representing this relationship. A sample of this relationship following physical stress in a healthy person is given in Fig. 2. This kymogram represents a "translation" of the amplitude-modulated waves of a ballistocardiogram to frequency-modulated signals. The integral of the work of the heart for any time segment can be determined by simply counting the number of marks on the paper.

The kinetics of the process under discussion is an external manifestation of the extremely complex nervous regulation of the cardiovascular system.

The proposed quantitative method of investigating the external work of the heart does not eliminate the necessity of analyzing the form-factor of the ballistocardiogram. However, we feel that the quantitative analysis will be very significant. In actual fact, it is much more convincing to say, for example, that, as the result of the action of strophanthin, the work of the heart changed by so many units or percent, than to judge some change in the notches of a ballistocardiogram.

## SUMMARY

A simple integration method for quantitative measurement of the cardiac impulses is presented. This method was developed for measuring the cerebral and muscular biocurrents. Ballistic impulses of the heart are recorded by means of a special device – an integrator – and are expressed in conventional units.